

# Visualization Tools to Support Proposal Submission

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## ABSTRACT

Many scientific observational programs require the Field Of View (FOV) or aperture to have a specific orientation on the sky. Since orientation requirements have a very strong impact on other aspects of the execution of the observation, an observer must have the ability to visualize the orientation of the science aperture and determine the effect of the orientation on the possible scheduling of the observation. We are prototyping an interactive, visual tool (The Visual Target Tuner, VTT) for fine-tuning the target location and orientation.

To make efficient use of any instrument the user needs to understand the various modes of the instrument and then calculate exposure times or signal-to-noise ratios for many different kinds of observations. Thus, the Exposure Time Calculator (ETC) is an essential tool that is used by various users for many different purposes. We are prototyping a more dynamic graphical ETC in which the user can simulate to some extent and determine the effect of various input parameters. This interactive exposure time calculator will not only be intuitive but will provide various users the different level of detailed information they desire.

The VTT and ETC are Web-based tools that can be used by themselves or as part of the Scientist's Expert Assistant, for the Next Generation Space Telescope proposal management system. Currently, the tools are being developed with the requirements of *HST* in mind, but will also be easily adaptable to other observatories. The underlying software for the tools is an object-oriented Java-based applet. The object-oriented nature of the design is intended to allow the tools to easily expand their features or to be customized. By making the system Java-based, we gain the ability to easily distribute the applet across a wide set of operating systems and users. In addition to executing the tools as a Java applet, it can be loaded onto a user's workstation and run as an application independent of a Web browser.

**Keywords:** visual tools, proposal development, exposure time calculator, target location, target orientation

## 1. INTRODUCTION

In the process of developing an observing program, the observer requires a number of inputs regarding the target and scientific instrument that need to be calculated/found/confirmed. Thus, the preparation of an observing program can be quite a daunting task. This task can be made easier by providing observers with a software tools environment that can be used to calculate/determine the various aspects of their observing program. The outputs of these various tools can then be used to fill in the proposal template. An important aspect of the tools environment is that it places tools in the hands of the observer so that he/she is then cognizant of the various issues. Further, the tools environment helps him/her craft a suitable observing plan. The overall goal of a tools environment is to ease the proposal preparation process, via easily available tools which access current information about the observatory and its instrument suite.

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## 2. GUIDELINES FOR THE GENERATION OF A TOOLS ENVIRONMENT

In discussing issues related to a tools environment, we make the following assumptions:

- **Purpose:** The primary purpose of the tools environment will be to provide the observer community with quality information and tools to help in the preparation of their observing program.
- **Users and Interface:** There are two categories of users: The external users and the internal users. The external users are scientists who are preparing observing programs for an observatory. The internal users are the observatory staff who provide observing support. The information that both these types of users is seeking must be up-to-date, useful and easy to find.

Tools should be developed with the two types of users in mind. The experienced user does not like to be walked through a tool, but already has a well developed idea that he/she might be testing. On the other hand, a first time user might like to be guided through the tool and its capabilities. Thus the usability and information content should satisfy the various types of users.

- **Documentation:** The various tools must be self explanatory whenever possible. If documentation is required it must be easily available on-line. Useful, simple examples must exist for each task to aid a beginner or to refresh an expert's memory.
- **Information Organization:** The organization of the tools environment and the tools must not only facilitate the needs of a first time user, but simultaneously not restrict an experienced user. The organization must be such that it highlights the various aspects of the task that need to be considered.
- **Quality Information:** The primary requirement of the tools environment is to provide users with quality information which can be easily accessed and used in developing observing programs. The tools should help decrease the complexity of a task whenever possible. Full technical and scientific details necessary for the completion of the task should be presented at an appropriate level of complexity. The tools should be maintained frequently in order to provide up-to-date information. The applicability of the tools should be properly discussed.

We are prototyping a new observation development system, the Scientist's Expert Assistant (SEA), for the Next Generation Space Telescope (*NGST*). Since our prototypes will be validated using Hubble Space Telescopes' (*HST*) Advanced Camera for Surveys (ACS) instrument (scheduled for installation in 1999) as a live test instrument, our tools are being generated somewhat in the frame work of *HST* operations. The SEA is described in an article entitled "An Expert Assistant System to Support the General Observer Program for NGST" also included in these proceedings . In this paper we describe two of the most commonly required tools that are being developed in the SEA environment. The current status, methodology, and direction in the development of these tools are also summarized below.

### 2.1. Overall Design Solution

The Visual Target Tuner (VTT; described in section 3) and the Exposure Time Calculator (ETC; described in section 4) are Web-based tools that can be used by themselves or as part of the SEA proposal management system. The underlying software for both the tools is an object-oriented Java-based applet. The object-oriented nature of the design is intended to allow both the tools to easily expand their features or to be customized. By making the system Java-based, we gain the ability to easily distribute the applet across a wide set of operating systems and users. In addition to executing the tools as a Java applet, it can be loaded onto a user's workstation and run as an application independent of a WWW browser. The architecture promotes the central location and maintenance of data such as instrument characteristics. For example, rather than embedding instrument and filter characteristics inside the applet, the ETC currently has a version that interfaces with STScI's "synphot" package for calculating the expected source and background counts. So if the transmission characteristic of a filter or detector changes, STScI staff can update their central data files and the ETC applet would automatically start using the revised numbers. The Java Foundation Classes are used for all user interface components. Where possible, existing libraries are reused, particularly in the area of astronomical algorithms. For example, we have imported many routines from the WCSTools library for use in coordinate system conversion from FITS images.

### 3. TARGET VISUALIZATION TOOL: THE VISUAL TARGET TUNER

#### 3.1. Overview and Motivation

Many scientific observational programs require the field of view (FOV) or aperture to be oriented in a specific way on the sky. Some of the specific uses of orientation are:

- long-slit spectroscopy of targets with specific directionality;
- fit the entire target of interest in the case of imaging;
- prevent a bright object from contaminating the FOV.

Further, in the case of the *HST*, where we have the capability to operate in parallel several instruments which share the optical telescope assembly FOV, one would like to visualize the FOVs of all the various instruments superimposed on the image of the sky. This allows adjustment of the orientation of the focal plane of the telescope so that the science output of all the parallel and primary observations can be maximized. Also in the case of *HST* an observer might like to know the availability of guide stars to determine if there could be a problem with scheduling the target.

Since orientation requirements have a very strong impact on other aspects of the execution of the observation, an observer must have tools to visualize the orientation of the science aperture and determine the effect of the orientation on the possible scheduling of the observation. In the following section we describe a visualization tool that we are developing to support proposal development.

#### 3.2. Requirements and Design Goals

The Visual Target Tuner (VTT) is a graphical tool for fine-tuning target coordinates and orientation of the FOV. The VTT will present an interactive image of the target area. Currently, for *HST* programs observers must independently research target information, and in many cases develop their own visualization software and manually enter the information into their observing proposal. When completed the VTT will have the following capabilities which are presently oriented for *HST* needs.

- The VTT visualization will present a model of the target area using data from astronomical databases, as well as allow user specified images to overlay onto the visualization model. The user will be able to manipulate these images in real-time, adjusting properties such as brightness, contrast, and color model. The VTT will also plot the FOV for specific instruments on an image for a given orientation angle.
- Navigating through the information contained within the visualization will be simple and intuitive. The user should be able to navigate through the target area by panning across the area or zooming in on a specific section. Detailed information about objects within the target area should be easily and quickly retrievable. Specifying the target position should be as simple as dragging the target indicator to the desired position in the visualization. The user might also choose to manually adjust the coordinates, or to perform a centroid fit on the target area.
- The user will be able to interactively rotate the displayed FOV to maximize the science requirements. The new orientation angle, with respect to detector coordinates, will be automatically provided to the observer. The VTT should continuously compute the rough schedulability of the observation given the currently selected constraints. This knowledge helps the user to maximize the schedulability of their observation, as they will quickly see if a specific constraint makes their observation unschedulable. The user should be able to easily experiment with their constraints to achieve the optimal schedulability.
- Often observers use the orientation requirement not only to get a preferred direction on the sky, but also to exclude regions of the sky. If they have a need to include or exclude specific objects, currently they must manually determine a specific orientation for the instrument FOV. Because an overriding goal during proposal creation is to maximize the schedulability of the proposal, and because a specific orientation severely restricts that schedulability, the VTT will allow the user to easily specify the areas that need to be included or excluded. The VTT should display these inclusion and exclusion points in the visualization and allow the user to interactively add and remove them. With this information, the VTT should determine the optimal orientation for the exposure and also provide a range of orientation angles that are acceptable. These multiple values can then be passed on to the scheduling system and thus make the program more flexible.

- Currently there are no visual tools to help predict the the impact of diffraction spikes, or CCD bleeding on the resultant image. The VTT will have instrument specific information to model the impact of these effects for a given orientation or for a given region of the sky. The ability to see these effects early in the development of the proposal, and to be able to adjust them interactively, should be an extremely powerful aid in reducing the overhead in submitting proposals.
- When used for *HST*, the VTT will have the ability to show the entire *HST* focal plane overlayed on the sky region, so that coordinated parallel observations can be carefully planned.
- For some *HST* observing programs, depending on the guide star availability, observers restructure their program or change the orient requirement. When knowledge of guide stars is made available the tool will also show the availability of guide stars, for the target position and orientation provided by the the user.
- The VTT will have the capability to allow the user to measure target coordinates to a reasonable accuracy when they are not easily available in the Guide Star Catalog (GSC). Often the observer has good data from elsewhere. There will be capability to import these images into the VTT, transfer the GSC reference frame onto the new image, and then measure target coordinates.

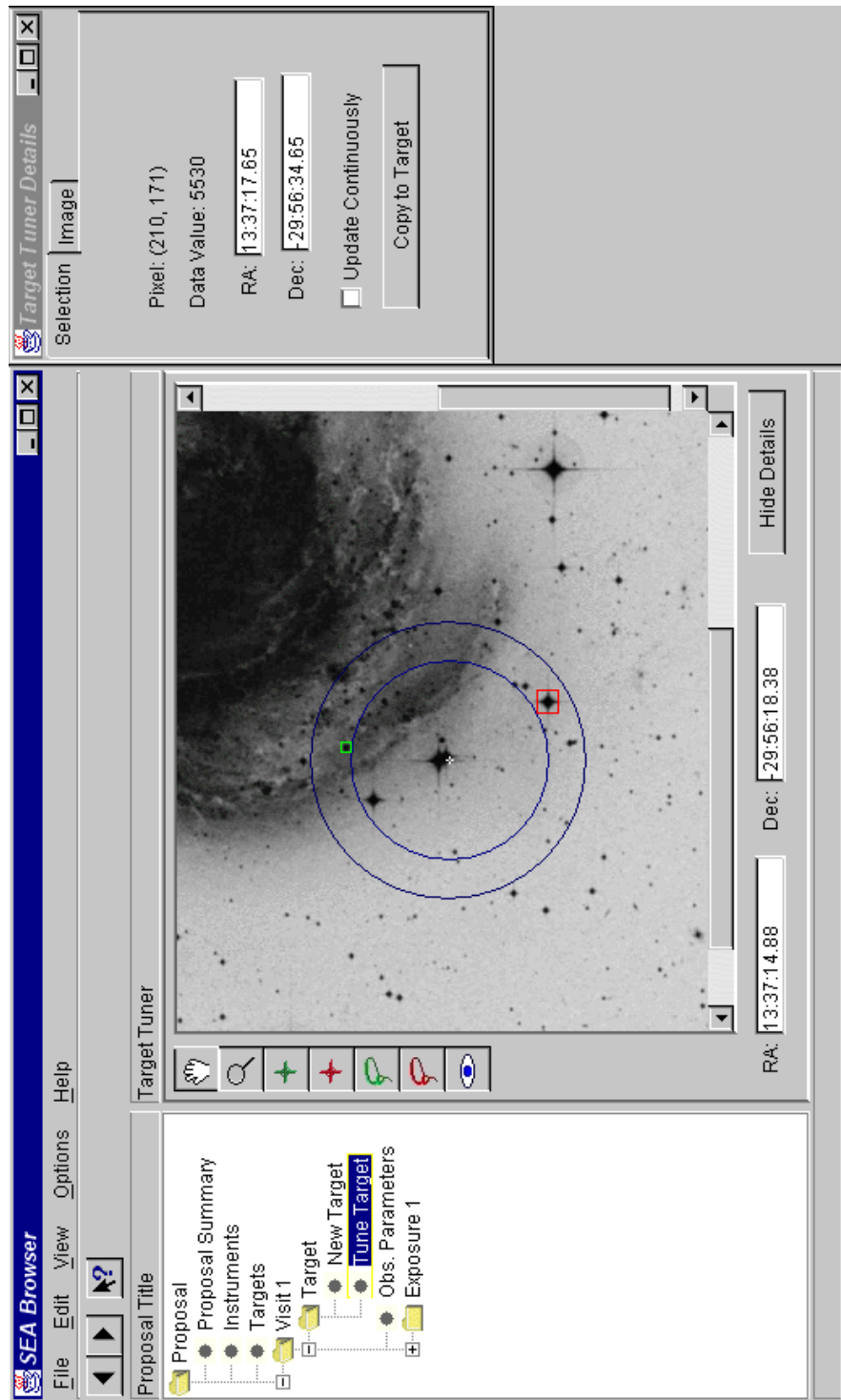
### 3.3. Design Solution

The VTT consists of a single editor which contains a main visualization area that occupies most of the window. One or more FITS images of the target area are contained within the visualization, along with a simple cross-hair to indicate the current position of the target. The target position is also shown as a set of coordinates in the bottom of the window. The user may change the position by dragging the target cross-hair or changing the values in the coordinate entry fields.

The visualization in Figure 1 shows two concentric circles: an inner circle contains the area that will be included in the exposure regardless of the orientation, and an outer circle contains the area that may potentially be included in the exposure. Thus, the two circles are the inscribed circle and the circumscribed circle for the aperture. The size and placement of these circles depends on the aperture of the specific instrument selected. We have used the ACS wide field camera aperture which has a size of  $200'' \times 200''$  in Figure 1. Orientation constraints are specified by selecting the inclusion or exclusion tool, and then selecting either an object or region in the visualization. Areas that must be included in the exposure are shown in green. Areas that must be excluded are shown in red. In the future, the tool will visually indicate the set of possible orientations, perhaps by shading the areas that will be excluded from the exposure. The user can also open a separate “Orientation Constraints” window to see how their constraints affect the schedulability of their proposal. They may monitor how the schedulability changes as they alter their inclusion and exclusion points in real-time.

The upper left corner of the VTT window contains the set of tools that may be used on the visualization. In addition, certain visualization options may be set using items under the “Options” menu. These options include the ability to toggle the display of specific elements in the visualization, such as the plate images, the modeled view, the aperture, the orientation constraints, and the set of possible orientations. The “View” menu provides access to secondary VTT windows. These include:

- an “Orientation Constraints” window that shows the inclusion and exclusion points as a table. This window also displays summary information about the schedulability of the proposal given the current set of constraints.
- an “Image Chooser” window that allows the user to specify the FITS image files to be shown in the visualization. The user may choose from the images retrieved from an astronomical database, or may specify a local image to use.
- an “Image Tools” window that allows the user to manipulate the images contained in the visualization. Images may be adjusted by changing their brightness, contrast, color table, or toggling the negative of the image.



**Figure 1.** The Visual Target Tuner window. For details see text.

### 3.4. Current Status and Development Timeline

We are currently developing an initial prototype of the VTT. This release will provide the ability to display a single FITS image of the target area and adjust the properties of the image. The user will be able to pan and zoom the image, fine-tune the target position by dragging the position or editing the position entry fields, and specify inclusion or exclusion areas on the target image.

The first full release, scheduled for September, 1998, will provide the ability to display multiple images within the visualization. This release will be more tightly integrated into the SEA, extending the scope of the VTT to include visit planning and image simulation. The VTT will be able to compute schedulability given the orientation constraints and will be able to display the set of possible orientations.

A later release, scheduled for 1999, will predict the impact of diffraction spikes and CCD bleeding on the resultant image. The ability to determine guide star availability and to display that availability on the visualization will also be included. This release will also include a modeled view of the target area to augment the target images.

## 4. EXPOSURE TIME CALCULATOR

### 4.1. Overview and Motivation

To make efficient use of any instrument the user needs to understand the various modes of the instrument and then calculate exposure times or signal-to-noise ratios (SNR) for many different kinds of observations. Observers find a need for exposure time calculators (ETC) during the development stage and observatory staff use the ETC throughout the year. The ETC therefore is an essential tool that is used by various users for many different purposes.

WWW-based software tools to aid the computation of exposure times or expected SNR for a number of target types are now available. The popularity of ETCs in the past year shows that such utilities are perceived by the community as valuable and important for proposal preparation.

Currently, the user provides input parameters by filling out a form in a WWW-based interface. Various calculations are done and then the ETC returns a set of tables, text and static graphs. We are generating a dynamic graphical interface in which the user can simulate to some extent and determine the effect of various input parameters. This exposure time simulator will not only be intuitive but will provide various users the different level of detailed information they desire.

### 4.2. Requirements and Design Goals

Simulating any exposure requires a set of input parameters to be selected by user. Some of these parameters are related to the target that has to be simulated, while other are related to the instrument. Thus, we see the ETC separated into the following four areas (folders). The user should have the ability to manipulate any number of parameters in one or all the folders. The final important component of the ETC is a graphical display where the effects of the user selected parameters on the exposure, SNR etc. are displayed. This graphical display will have zoom in/out capability, and the ability to adjust cross-hairs to determine a particular value. Further, an important capability of the ETC should be the ability to store/print all/selected information, and the ability to track down a problem. We now discuss each of the folders, the graphical interface and other capabilities in detail.

#### 4.2.1. The target information folder

This folder contains all the user supplied target information. The important user supplied parameters in this folder are:

- **Morphology:** The ETC will be able to simulate information for point sources, compact sources, and extended sources. The user will have to specify the size of the source, its surface brightness distribution (if compact or extended). A number of distribution functions (such as flat, exponential or DeVaucouleurs' law) will already be considered. The ETC will have the ability to accept user defined distribution functions as well. For an extended source, the ETC will have template morphologies (such as, flat distribution, elliptical, spiral, user supplied).
- **Nature of the Spectral distribution:** Various types of spectral energy distributions will be included in this category. Examples are: User supplied spectrum, Kurucz Models for the different stellar types, Non-Stellar Objects, Power laws, Blackbody distribution, *HST* standard stars.

- **Normalization:** The user must specify what normalization must be used for the spectral energy distribution defined. The redshift of the object also needs to be specified.
- **Other characteristics:** In this section the user supplies any other relevant information. Presently, this could be the amount of extinction towards the source and the extinction law that should be used. The ETC will support the Galactic extinction law and the LMC extinction law. Later this can be extended to other characteristics.

#### 4.2.2. The instrument information folder:

This folder contains the instrument mode that the user would like to use. We divide this information into two sections, the first section would contain the parameters that define the observation mode, and the other section contain parameters that the user would iterate upon.

- **Observation Mode:** This contains information such as the instrument detectors, filters, quality of the available calibration files.
- **Exposure Details:** This will allow the user to manipulate quantities such as exposure time, signal-to-noise (SNR) ratio, gain, CR-Split, dark-noise, and read-noise.

#### 4.2.3. The visit constraints folder:

This folder contains information that will place constraints on the observations at the visit level. These parameters are: the amount of Zodiacal Light, the amount of Earth Light seen by the detector, the Geo-coronal background, and the scattered light.

#### 4.2.4. The graphical folder:

The graphical section of the ETC is the heart of this tool. It will show the following:

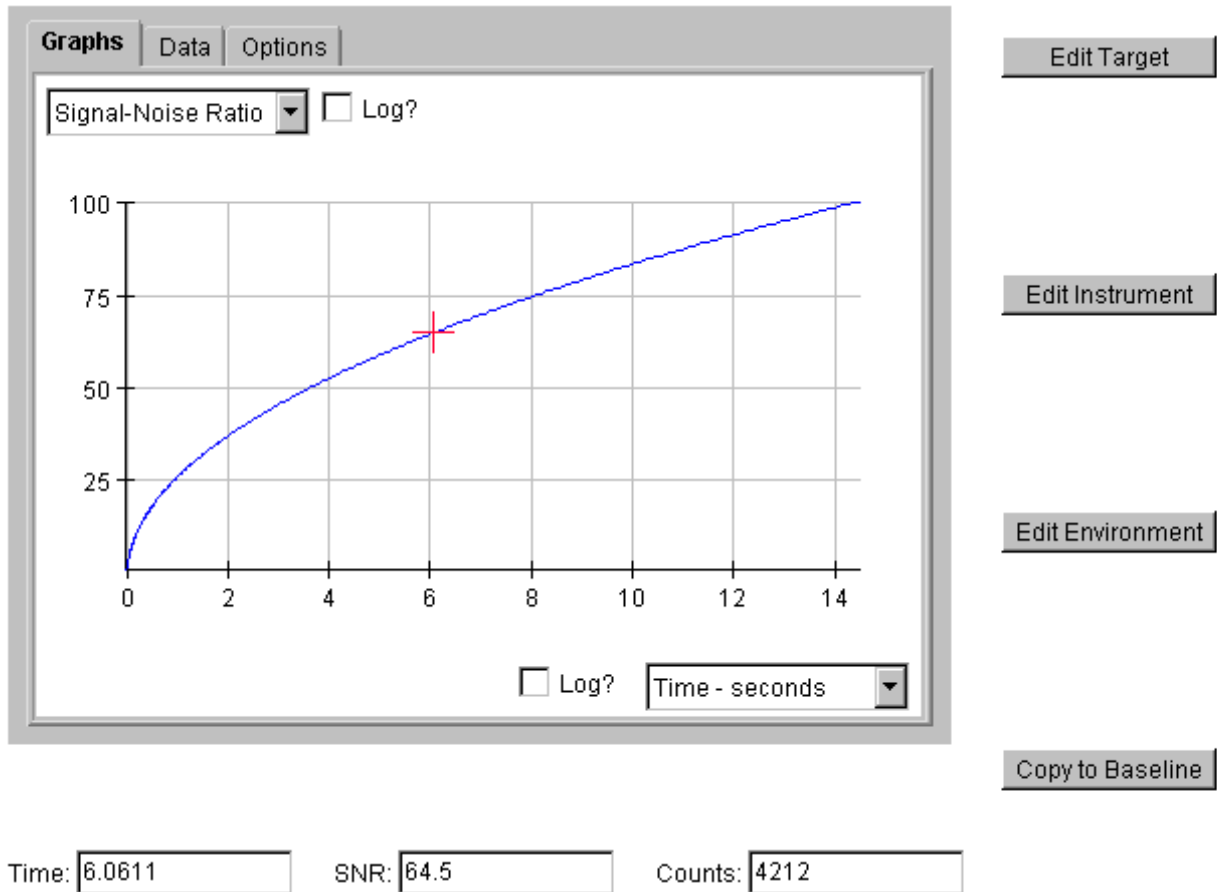
- **SNR vs. time:** This is a classical ETC output. The cosmic ray rate will be evaluated and displayed as an output for the proposed time.
- **Flux vs. time:** This type of plot will allow a user to determine the limiting magnitude that a certain allocation of time will provide. This should not only plot the flux vs. time for a given SNR, but also plot flux vs. time for 0.5 (SNR) and 1.5 (SNR). Thus, a user is provided information on a range of exposures in one instance and does not have to re-submit a new calculation. The effect of CR split should also be assessed.
- **SNR vs. Flux:** Given a fixed time (T) a user should be able to determine the SNR relation with flux. Once again there should be an evaluation of SNR vs. flux for 0.5T and 2.0T.

There will be a location in this folder that allows users access to intermediate results such as the brightest pixel counts, counts from the source, counts from the sky, counts from other sources of background, detector noise etc. Many of these values could also be graphically represented. The results of the ETC may be stored in a file or output to a printer. Once an image using the ETC is simulated, it will have the capability to store that image as a FITS image that the user can later manipulate. The image can also be stored as a postscript file, along with the relevant parameters that were used to simulate the image.

### 4.3. Design Solution

The ETC seeks to improve on existing exposure time calculators by providing real-time interactive graphs showing SNR and source counts across a range of exposure times and wavelengths. Users can easily modify the target or instrument parameters and quickly see the effects on the exposure.

Visually, the ETC's central component is the real-time graph (see Figure 2). Rather than being limited to a fixed set of data, the ETC allows the user to choose what data are to be displayed on either the X- or the Y-axis. Currently, the ETC can graph exposure time, Signal-to-Noise Ratio, and total counts. The user can change the data displayed in the graph by selecting a data type from the choice boxes at the graph's axes ("Signal to Noise Ratio"



**Figure 2.** The Exposure Time Calculator window. For details see text.

versus “Time”, for example). A user can click on any point on the plot and have all the data about that point displayed. Fields along the bottom of the screen always show the key data: exposure time, signal-to-noise ratio, and source counts. The graph, however, can be replaced with a tabular view by selecting the “Data” tab. In the “Data” tab additional details (such as background counts, maximum time before a detector’s buffers will overflow, etc) about the exposure are included. Likewise, selecting the “Options” tab replaces the graph with a series of options that allow the user to adjust the look of the graph. The “Graphs” tab returns to the graphical display. Figure 2 shows the ETC with the “Graphs” tab selected.

In addition to the central graphical component, the user can edit the instrument parameters and within that form request to see a graph of the transmission efficiency of the current instrument configuration.

The underlying architecture of the ETC is also designed to support saving and re-loading of an exposure and “dragging-and-dropping” of part of a previously modeled exposure on a new exposure. For example, a user might want a complex spectrum defined in one exposure which they might save on their workstation. Then they could load a new exposure applet and load the previous spectrum simply by “dragging” its icon from their workstation desktop and “dropping” it on the new exposure applet.

#### 4.4. Current Status and Development Timeline

We are currently testing a beta release at the STScI. By the end 1998 we plan to add two new key features: (a) the ability to simulate spectroscopic data, and (b) the ability to simulate imaging data. The simulations will be updated in real-time as the user changes properties of the exposure. We anticipate that it will result in the VTT and the ETC being integrated tightly together. A user will be able to start with a displayed FITS image of an existing image,

specify new instrument and/or target parameters and ask to show the VTT/ETC to display what the new image might look like given what is known about the target's spectrum.

## **5. SUMMARY AND RECOMMENDATIONS**

The tools environment consisting of the VTT and ETC tools that we are developing will be extremely useful to observers in the preparation of their observing programs. The new Java applet technology provides us with the dynamic graphical interface that we desire for our tools environment. A WWW-based tools environment is a live document that can be periodically updated and enhanced. Implicit in our philosophy is the need for WWW-based supporting documents. The popularity of the existing WWW-based tools shows that such utilities are perceived by the community as valuable and important. Investing further in enhancing the present tools environment available to the astronomical community would be of great benefit.

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